

Prioritizing Conservation Areas: A GIS Based Approach

Peter J. Unmack and William H. Schaedla

Introduction

The majority of conservation efforts focus on a specific species or a suite of species (a biotic community). Alternatives, like process oriented and ecosystem based schemes, may be philosophically preferable (Morrissey *et al.*, 1994), but are simply not viable. There is no fixed consensus about what constitutes a process or an ecosystem (Meffe and Carroll, 1994). This makes them difficult to define for management purposes and hard to protect legislatively. Beyond this, biotic processes and systems are largely the results of species interactions. They are protected when the species that cause them are protected. The converse is not always true. An alarming number of ecological processes remain intact even when species presumably responsible for them are extirpated (Tracy and Brussard, 1994).

While species based approaches are preferable to other types of conservation, they are not an easy proposition. Species conservation is subject to a variety of requirements, including: 1) the need that data used in planning reflect real world conditions; 2) the need to identify potentially significant conservation areas; and 3) the need for hierarchies that allow prioritization of conservation areas. The first two are largely self-evident. Obviously, species based conservation can only take place if the target species are present. Likewise, it can only be effective if the data employed indicates the overall state of the target species. Such data must display accurately where the species is found and any population trends that affect it.

The third requirement for effective species based conservation is less straightforward than the other two. Prioritization, or ranking, of conservation efforts is subject to a variety of considerations. Which is more important in planning, high species diversity, threatened species diversity, or intact species assemblages? These alternatives must be brought together into a logical hierarchical ranking that allows defensible conservation choices.

Here we present a stepwise methodology for prioritizing conservation areas in the southwestern USA. Our technique utilizes museum collection records of fishes that have been registered spatially in a geographic information system (GIS). Our database contains 5,154 points

and spans a period dating from 1840 to 1995. It covers the Gila Basin, a major tributary to the lower Colorado River. The Gila River rises in western New Mexico and flows through Arizona eastward to Phoenix. Along the way, it collects water from several major tributaries before reaching Phoenix. From Phoenix the river flows southwest to Yuma and joins the Colorado River (Figure 1). A total of 19 native and 45 exotic fish species have been recorded from throughout the drainage. Seven native fish are now extinct or extirpated from the drainage, and much of the native fauna has suffered significant declines. Five extant species are listed federally by the United States government as threatened or endangered. Only three are considered widespread and common. The causes of decline are many. However, the principal threats are introductions of exotic species and habitat destruction resulting from dams (Minckley and Deacon, 1991).

Our data provide the most accurate characterization of fish diversity available. They also show trends in species occurrences over the last 150 years. As a result we were able to develop alternative conservation hierarchies based on several factors.

Methods

We performed geographical manipulations on a Hewlett Packard 712/60 running HP-UX 10.2©. We also used i486 hardware running Microsoft Windows 98© for numerical manipulations. Our fish data were originally obtained from museum collection databases and digitized via ArcEdit©, a GIS software package manufactured by Environmental Systems Research Institute (ESRI). We created watershed themes in the GIS by manipulating USGS Digital Elevation Models (DEMs) with a mix of commands in Grid© (ESRI). We then edited these watershed themes manually to correct their boundaries and gave major streams 1 km buffers on each side as this was the approximate maximum margin of error for fish point data. We created stream buffers for the watersheds because traditional watershed models do not incorporate major streams, but most fish records occur along them. Finally, we converted fish point data into polygon themes based on individual species occurrence in watersheds using ArcPlot© (ESRI). We then transformed these polygons into grids.

In this study we used five GIS themes. These included: total native fish diversity from 1840 to 1995, post 1980 fish diversity, post 1980 threatened fish diversity, percentage native fish

decline, absolute native fish decline and exotic fish diversity. We created these themes by adding the individual species grids outlined above. We used ArcView 3.1©(ESRI) for these manipulations.

Due to the nature of grids, the boundaries between values usually contain a line of cells with intermediate values of adjacent surrounding areas. To overcome this we buffered the original watershed polygon cover by -200m (2.5 times the size of a grid cell). We then used this cover to summarize by zone our within theme data. Despite this buffering, the summarize by zone command returned incorrect values. As an alternative, we converted the watershed polygon cover to a grid and used it as the zone theme. This improved the values, but errors still occurred. Fortunately, these errors were small, and median values of the summarize theme were accurate.

We summarized each of our five initial themes by zone using the technique described above. Next we joined the output from summarize by zone to the zone's theme table (using the field for the individual watershed as a common value). We then exported the table as a database file (.dbf), added it into the GIS project file (.apr) and edited it to remove unnecessary fields (all but value, area and median). We used our edited file to create a new theme, which we calculated to equal median and named after the summary theme. We then merged our edited file with the next summarize by zone and exported it, repeated this process until values from the summarize by zone outputs were in the same .dbf file. Throughout our manipulations, we used the area field to double check that we were comparing the correct watersheds across all themes.

We imported our final tables into Microsoft Excel 97© to calculate regressions of the various factors against each other. This allowed us to see if there were any trends or interactions between them. Our comparisons included: post 1980 fish diversity, post 1980 threatened fish diversity, percentage native fish decline, absolute native fish decline and exotic fish diversity.

Based on the Excel© comparisons we manipulated the grids based on value fields. We reclassified all watersheds with zero decline in native fish, giving them a value of one. All others we gave a reclassified value of zero. Likewise, we reclassified threatened fish as a value of 20 for >40% threatened species, 10 for 15-35%, and 0 for 0%. These ranges included all values present. As a final step, we added the decline and threatened species grids to create a new theme with seven categories.

Results

There was no clear relationship between exotic fish diversity and any other categorization (except they frequently out-numbered native species), hence we eliminated it. Percentage native fish decline was relatively uninformative when compared to absolute native fish decline due to the wide variation in percentages of decline relative to the absolute declines (e.g., for a decline of one species, percentage decline varied from 14 to 100%, similarly for a decline of 2-4 species percentage decline varied between 40 and 100%). There was no clear relationship between absolute decline and post 1980 diversity except sites of highest diversity (7 and 8) had suffered no decline, and lower diversity watersheds had often experienced a significant decline. Comparing percentage decline against both post 1980 and threatened diversity revealed similar trends (i.e. higher diversities had suffered lower declines). Given the wide variation in absolute and percentage decline we divided this factor into two values, watersheds with no decline and those with some decline in fish species diversity as one of our conservation weightings. If degree of decline were to be incorporated we suggest that percentage decline gives a more accurate assessment of intactness. A good correlation exists between post 1980 native and threatened fish diversity ($R^2 = 0.69$). When we divided present diversity by threatened diversity, three categories became apparent, a group of higher values between 40 and 66% with only a species diversity of one having 100% threatened diversity. Many sites with low and intermediate diversity had between 15 and 35% threatened species, while many sites containing four or less species had no threatened species. The first category "captured" all the watersheds with a high percentage of threatened fish as well as those with highest diversity values. The second allowed for low, but possibly important populations of threatened species to be identified. These values corresponded well with increasing species diversity, capturing two important variables and combining them into one value. This defined our second variable for assessing conservation significance. Hence, a ratio of post 1980 and threatened fish diversity was given three unique values, 20, 10, and 0 and percentage decline in native fish was given two values, 1 and 0 (see Table 1).

Overall, of the 279 watersheds in the Gila Basin, 162 contained native fishes and merited a conservation value (Figure 2). For a breakdown of the individual values contained within each conservation ranking see Table 1. Note that conservation rankings need not be taken as higher values indicating higher conservation value (although we suggest this would be reasonable).

Conservation significance depends upon what managers consider the most important weightings to be. Our scheme provides only alternatives.

Table 1

characteristic	total # of watersheds	present day diversity values (# of watersheds)
no fish records	117	-
not intact, no threatened species	88	0 (51), 1 (18), 2 (15), 3 (3), 4 (1)
intact, no threatened species	25	1 (13), 2 (8), 3 (3), 4 (1)
not intact, 15-35% threatened species	15	3 (5), 4 (4), 5 (2), 6 (4)
intact, 15-35% threatened species	17	3 (4), 4 (4), 5 (6), 6 (3)
not intact, >40 % threatened species	11	1 (5), 2 (4), 4 (1), 5 (1)
intact, >40 % threatened species	6	2 (1), 3 (1), 6 (2), 7 (1), 8 (1)

Discussion

These results should be viewed as provisional. Areas identified need to be further investigated via field studies to confirm results. This is necessary as some areas may have received lower values due to a lack of adequate sampling data. Future analyses based on this methodology should also make efforts to incorporate the number of collections and/or species records per watershed and their occurrence over time to more accurately assess if some watersheds are inadequately sampled (work is in progress to make this information available from the database). Abundance data is of little value as fish populations are known to undergo major shifts in abundance over time (Deacon and Minckley, 1974). A broader investigation of the patterns leading to native fish decline could be undertaken if data could be obtained. This may be useful in identifying factors responsible for native fish decline and allow for corrective management. Additionally, an important consideration of this study is the scale of analysis. If areas are identified as significant, they can be re-examined at finer resolution to identify specifically the important

habitats within watersheds. For example, springs often provide high native fish diversity and low exotic fish diversity (e.g., Spring Creek near Page Springs has five native fish, whereas other sites in this watershed have few if any native fish remaining). Identification of these localized areas is important, especially given the fragmented occurrence of some native fish populations (due to both natural and human causes).

Finally, it should be noted that our methodology provides a ranking scheme, but the order of this scheme is not fixed. It is a function of the different weightings we assigned to intact biotic communities and to the percentage of threatened species diversity within areas. We ordered areas against one another rather than against some static or idealized set of conservation criteria. This classification method created a scale for conservation wholly dependent upon the situation at hand, rather than on an inflexible ranking. Whether the methodology here is applicable to other situations remains to be tested. However, we feel there is nothing in this technique that restricts its use to aquatic systems or to North America.

References

- Deacon, J.E and W.L. Minckley. 1974. Desert Fishes, In: *Desert Biology*, vol. 2. Brown W.G (Ed). Academic Press, New York, pp 385-488.
- Meffe, G.K. and C.R. Carroll. 1994. *Principles of Conservation Biology*. Sinauer, Sunderland, MA.
- Minckley, W.L. and J.E. Deacon. 1991. *Battle Against Extinction*. University of Arizona Press, Tucson, Arizona.
- Morrissey, W.A., J.A. Zinn, and M.L. Corn. 1994. *Ecosystem Management: Federal Agency Activities*. Library of Congress, Congressional Research Service, Washington, D.C.
- Tracy, C.R. and P.F. Brussard. 1994. Preserving biodiversity: species in landscapes. *Ecological Applications*. 42: 205-207.

Figure 2. Classification Scheme

